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(54) **LIGHT ASSEMBLIES FOR ELECTRONIC DEVICES**

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(51) **Int. Cl.**
G10L 21/00 (2013.01)
F21V 8/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G02B 6/0096*** (2013.01); ***F21V 7/04*** (2013.01); ***F21V 7/043*** (2013.01); ***F21V 15/01*** (2013.01);
(Continued)

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CPC ... F21V 33/0056; F21V 7/043; G02B 6/0096; F21Y 2101/00
See application file for complete search history.

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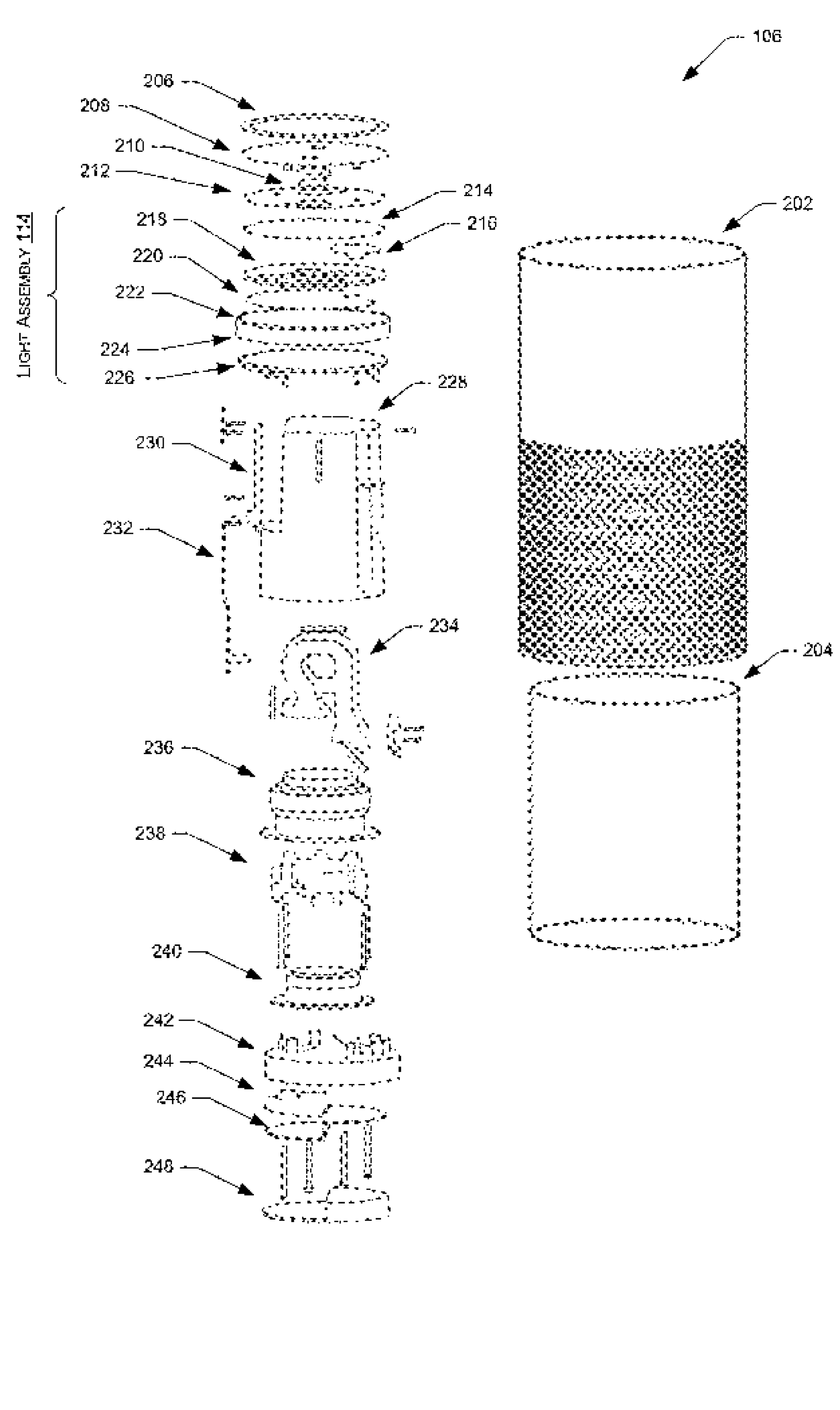
Primary Examiner — Tracie Y Green
(74) *Attorney, Agent, or Firm* — Lee & Hayes, P.C.

(57) **ABSTRACT**

Devices that include light assemblies for providing visual feedback to users that operate the electronic devices. In some instances, the devices comprise voice-controlled devices and, therefore, include one or more microphones for receiving audible commands from the users. After receiving a command, for instance, one such voice-controlled device may cause a corresponding light assembly of the device to illuminate in some predefined manner. This illumination may indicate to the user that device has received the command. In other instances, the devices may illuminate the lighting assembly for an array of other purposes. For instance, one such device may illuminate the corresponding light assembly when powering on or off, playing music, outputting information to a user (e.g., via a speaker or display), or the like.

20 Claims, 10 Drawing Sheets



Related U.S. Application Data

continuation of application No. 15/417,895, filed on Jan. 27, 2017, now Pat. No. 10,162,106, which is a continuation of application No. 14/502,429, filed on Sep. 30, 2014, now Pat. No. 9,574,762.

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F21V 17/06	(2006.01)
F21V 7/04	(2006.01)
G10L 15/22	(2006.01)
F21V 33/00	(2006.01)
F21V 15/01	(2006.01)
G08B 5/36	(2006.01)
G10L 15/30	(2013.01)
F21Y 115/10	(2016.01)

(52) **U.S. Cl.**

CPC ***F21V 17/06*** (2013.01); ***F21V 33/00*** (2013.01); ***F21V 33/0056*** (2013.01); ***G02B 6/0031*** (2013.01); ***G08B 5/36*** (2013.01); ***G10L 15/22*** (2013.01); ***G10L 15/30*** (2013.01); *F21Y 2115/10* (2016.08); *G10L 2015/223* (2013.01)

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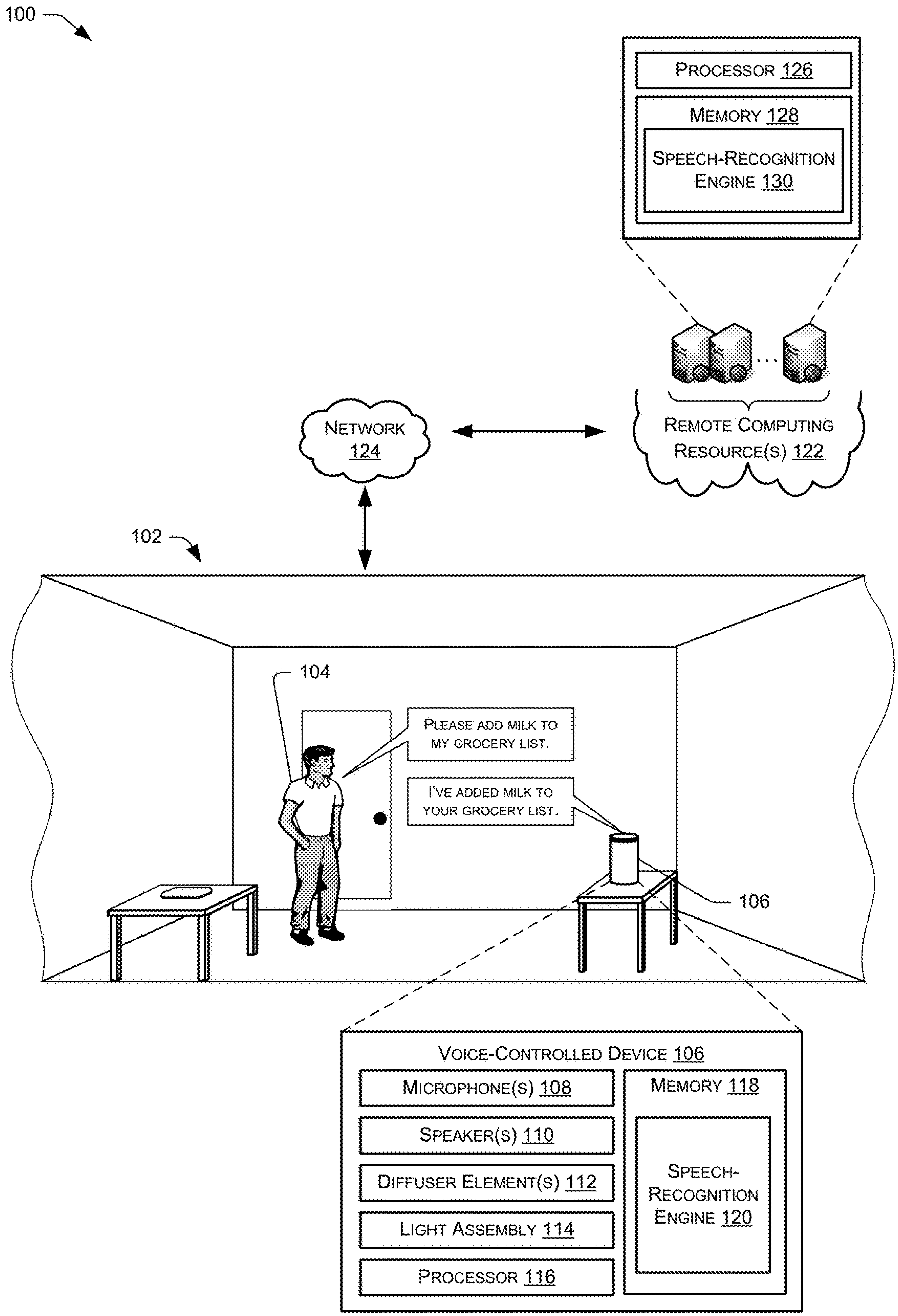
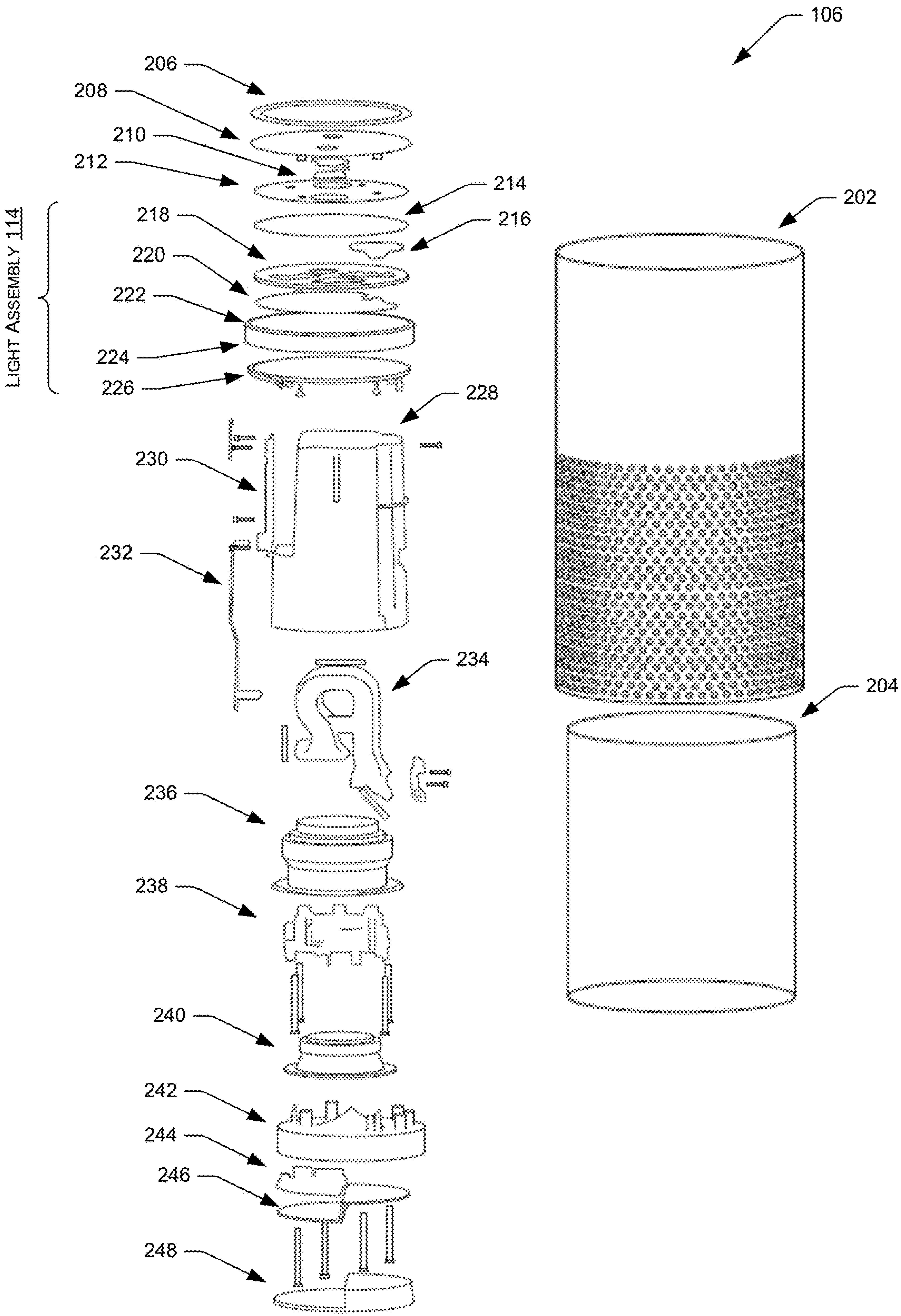

100
Processor 126
Memory 128
Speech-Recognition Engine 130
Network 124
Remote Computing Resource(s) 122
102
104
Please add milk to my grocery list.
I've added milk to your grocery list.
106
Voice-Controlled Device 106
Microphone(s) 108
Speaker(s) 110
Diffuser Element(s) 112
Light Assembly 114
Processor 116
Memory 118
Speech-Recognition Engine 120

Fig. 1



106
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LIGHT ASSEMBLY 114
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Fig. 2

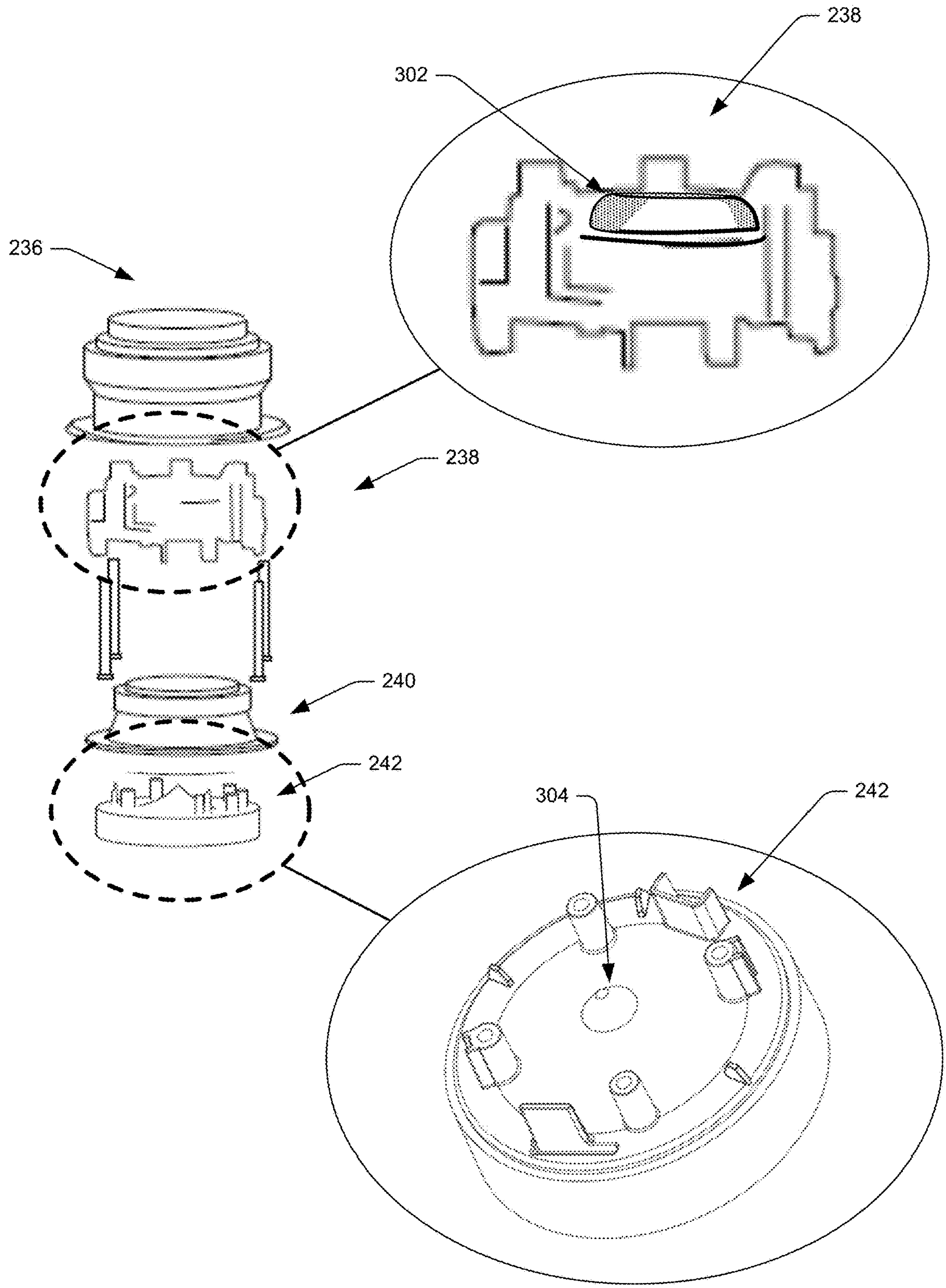


Fig. 3

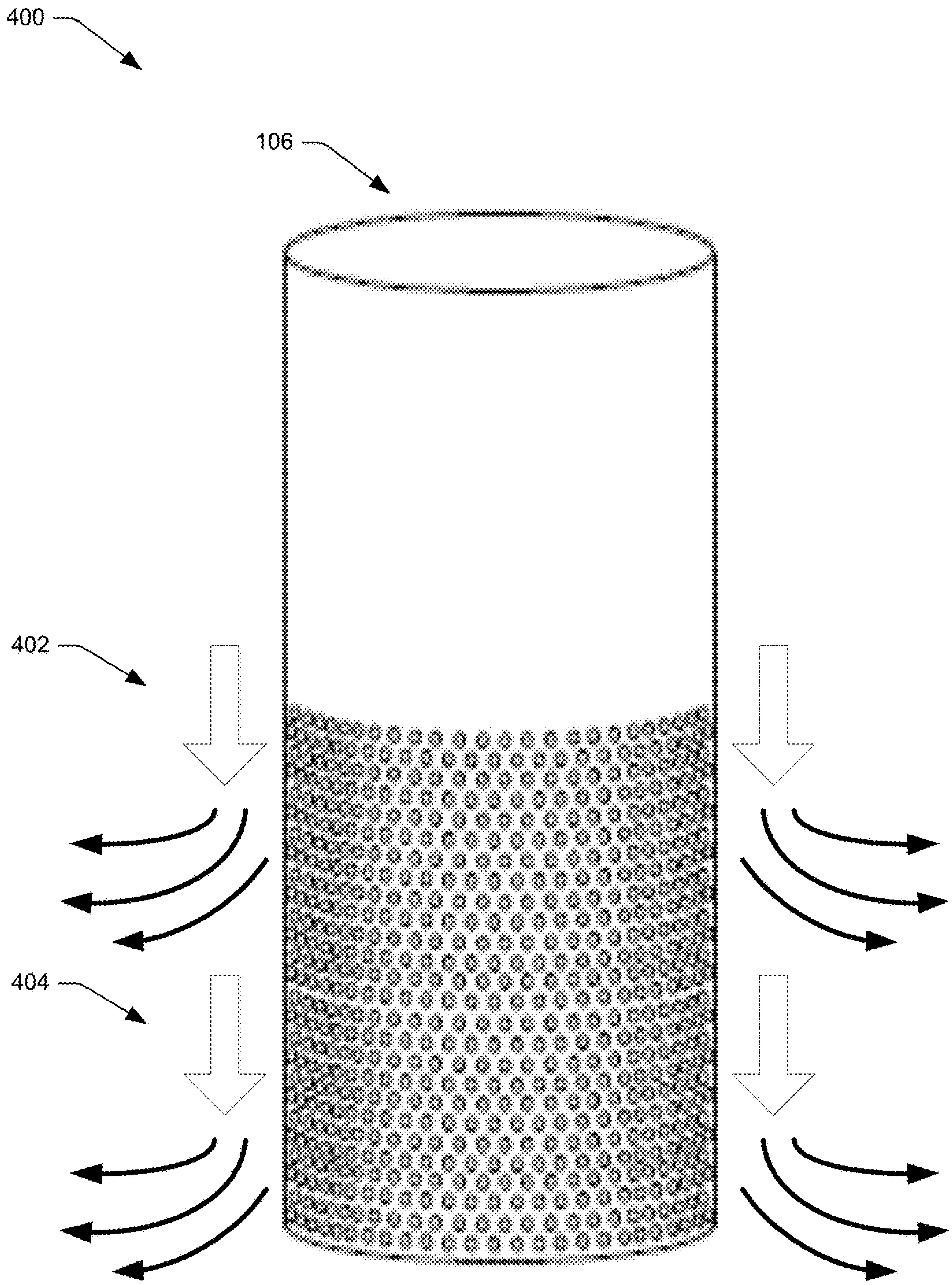


Fig. 4

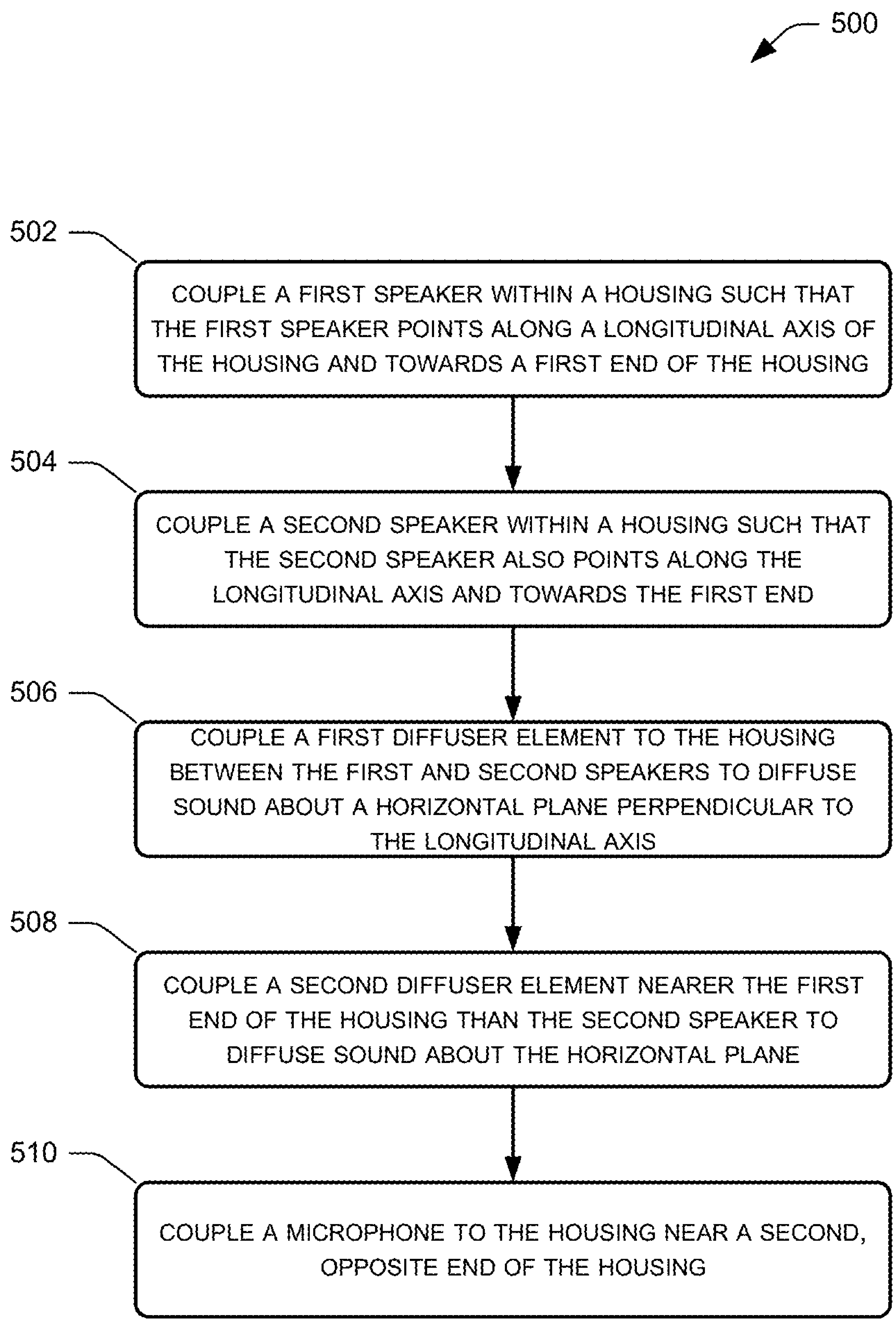
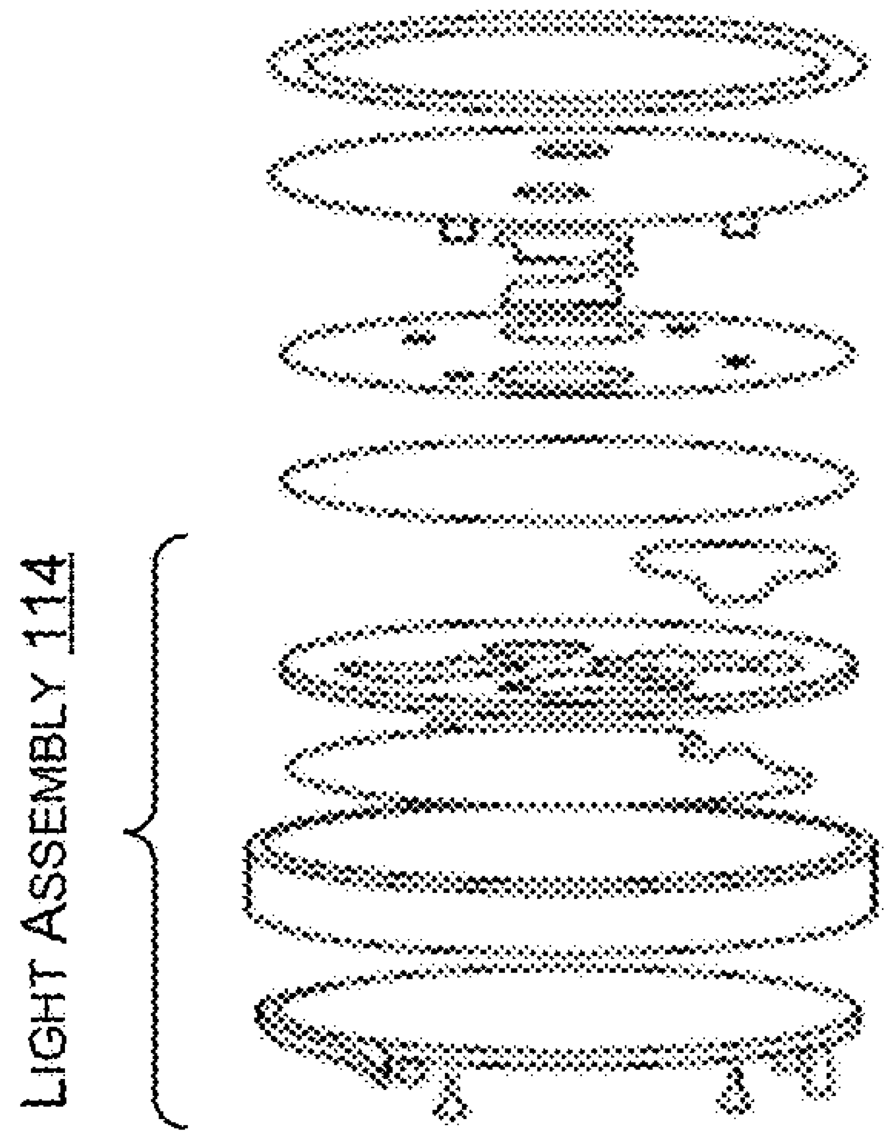

500
502
COUPLE A FIRST SPEAKER WITHIN A HOUSING SUCH THAT THE FIRST SPEAKER POINTS ALONG A LONGITUDINAL AXIS OF THE HOUSING AND TOWARDS A FIRST END OF THE HOUSING
504
COUPLE A SECOND SPEAKER WITHIN A HOUSING SUCH THAT THE SECOND SPEAKER ALSO POINTS ALONG THE LONGITUDINAL AXIS AND TOWARDS THE FIRST END
506
COUPLE A FIRST DIFFUSER ELEMENT TO THE HOUSING BETWEEN THE FIRST AND SECOND SPEAKERS TO DIFFUSE SOUND ABOUT A HORIZONTAL PLANE PERPENDICULAR TO THE LONGITUDINAL AXIS
508
COUPLE A SECOND DIFFUSER ELEMENT NEARER THE FIRST END OF THE HOUSING THAN THE SECOND SPEAKER TO DIFFUSE SOUND ABOUT THE HORIZONTAL PLANE
510
COUPLE A MICROPHONE TO THE HOUSING NEAR A SECOND, OPPOSITE END OF THE HOUSING

Fig. 5



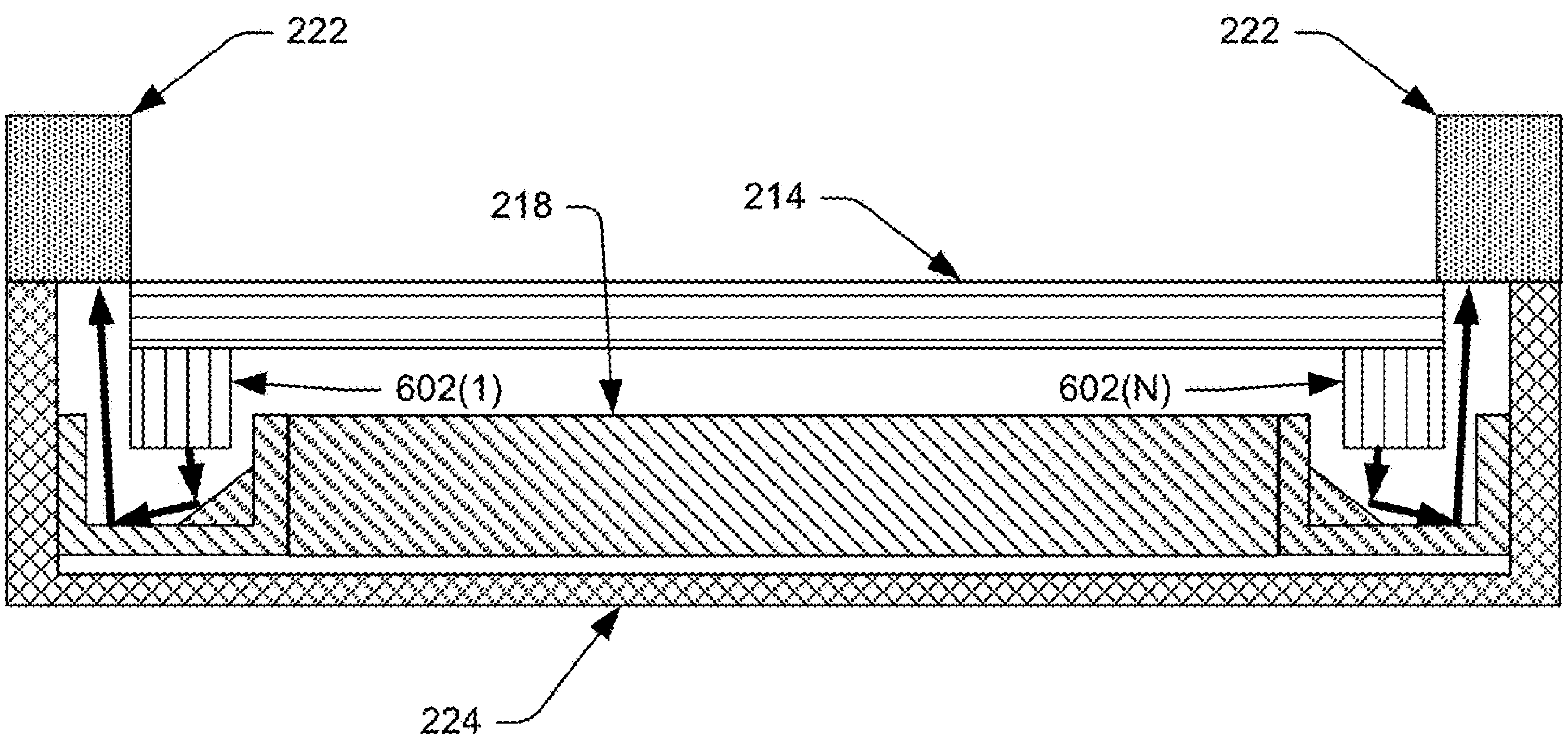
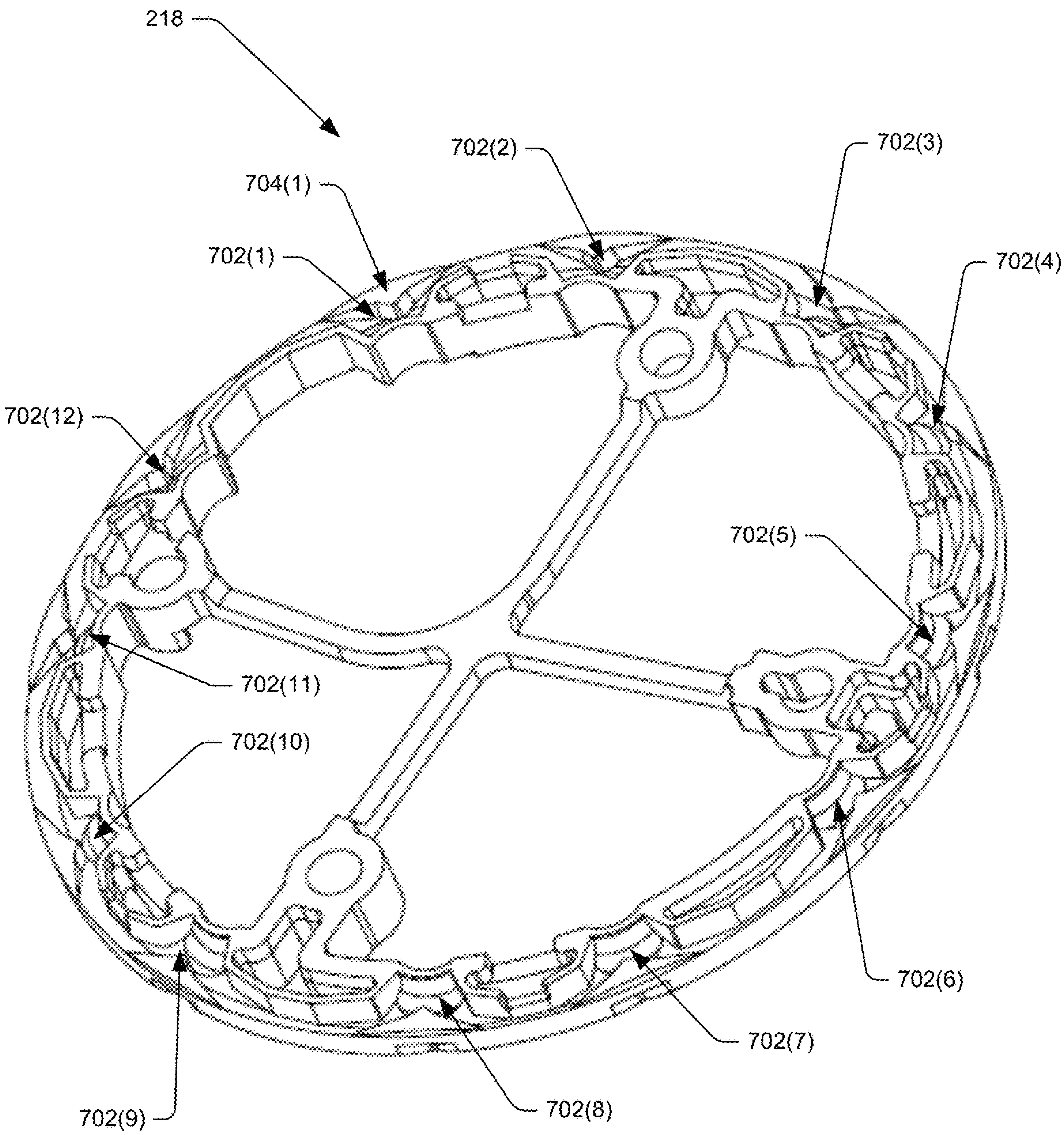


Fig. 6


218
702(2)
702(3)
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702(11)
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702(7)
702(9)
702(8)

Fig. 7

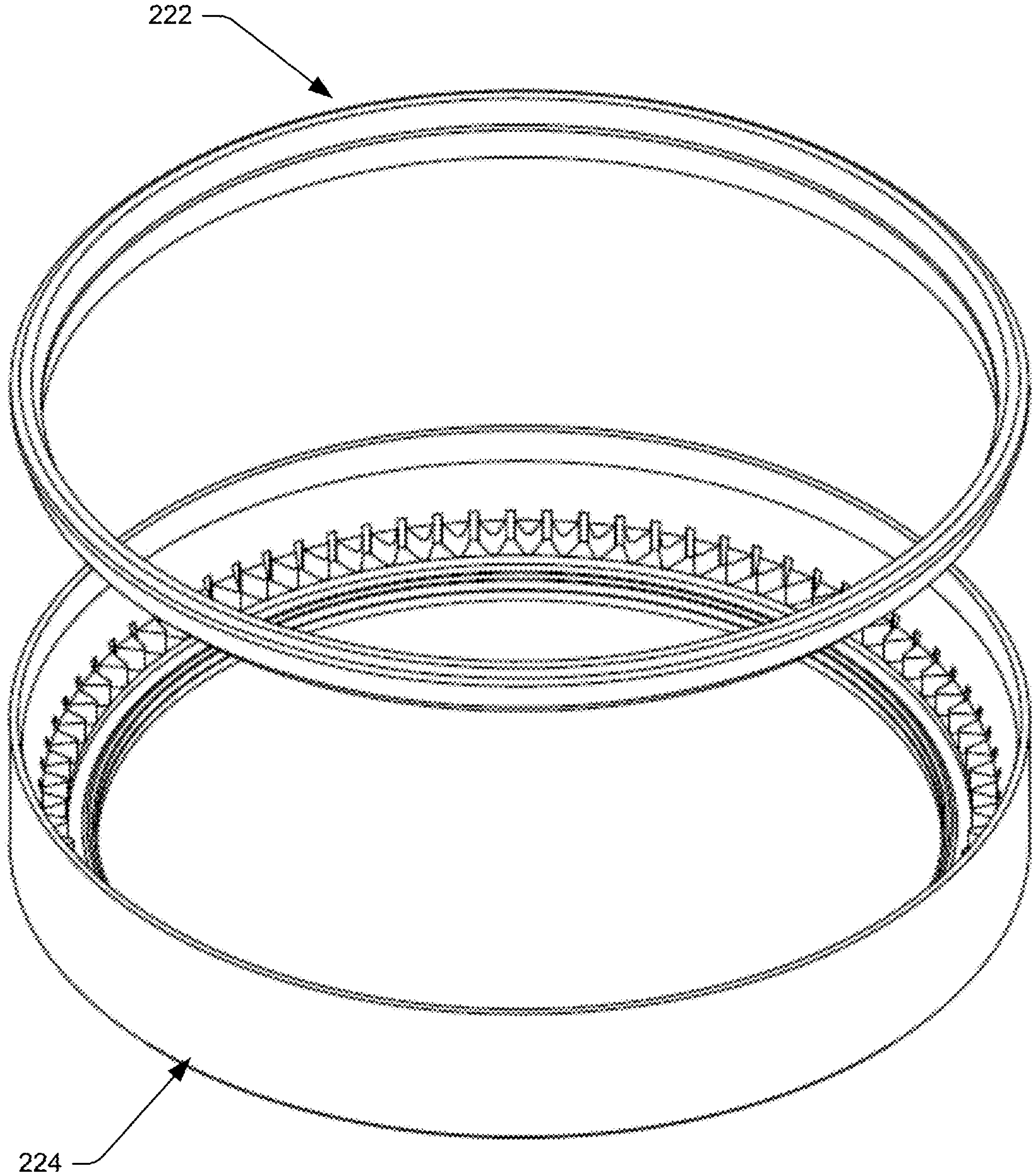

Fig. 8

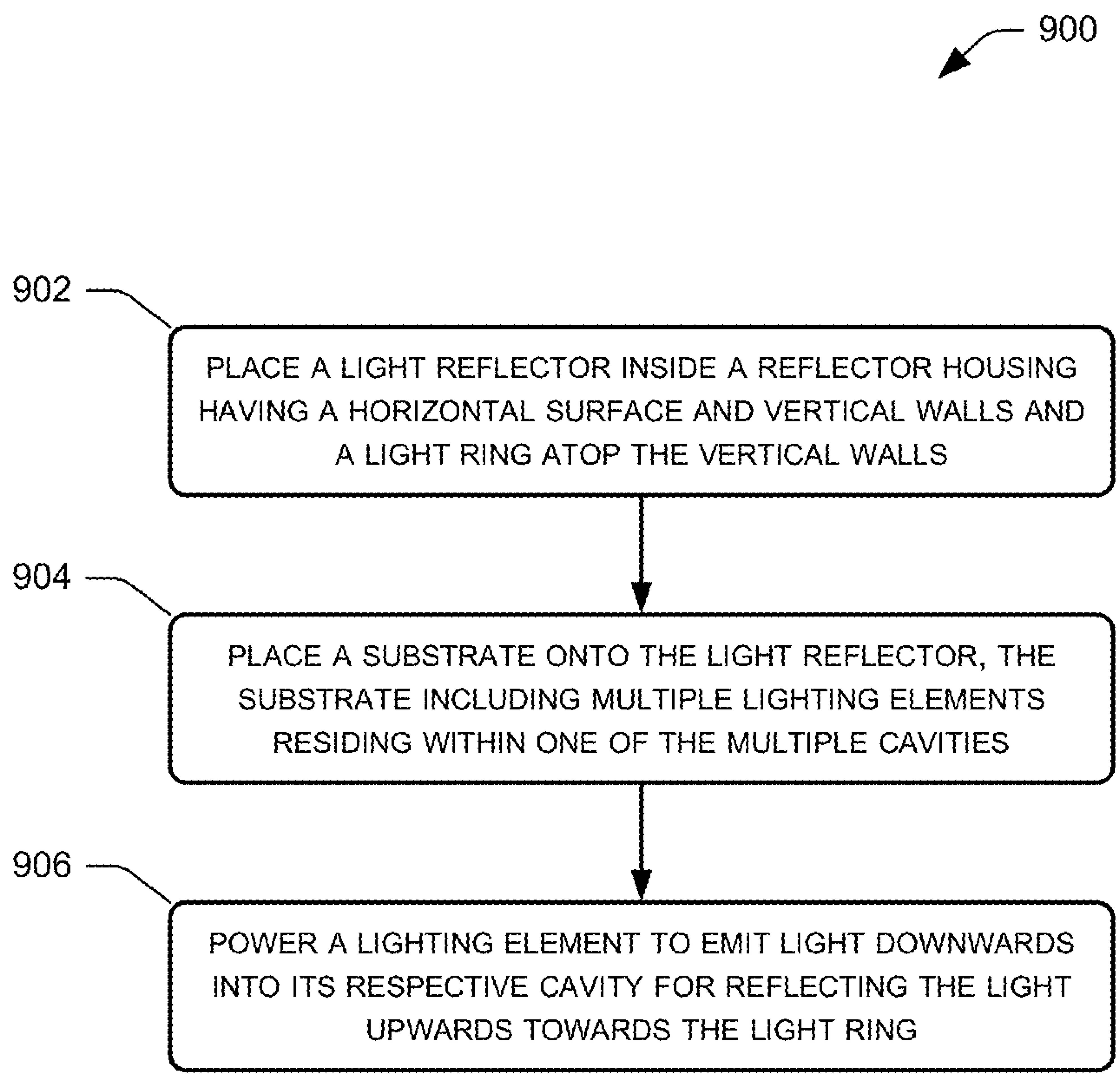
900
902
PLACE A LIGHT REFLECTOR INSIDE A REFLECTOR HOUSING HAVING A HORIZONTAL SURFACE AND VERTICAL WALLS AND A LIGHT RING ATOP THE VERTICAL WALLS
904
PLACE A SUBSTRATE ONTO THE LIGHT REFLECTOR, THE SUBSTRATE INCLUDING MULTIPLE LIGHTING ELEMENTS RESIDING WITHIN ONE OF THE MULTIPLE CAVITIES
906
POWER A LIGHTING ELEMENT TO EMIT LIGHT DOWNWARDS INTO ITS RESPECTIVE CAVITY FOR REFLECTING THE LIGHT UPWARDS TOWARDS THE LIGHT RING

Fig. 9

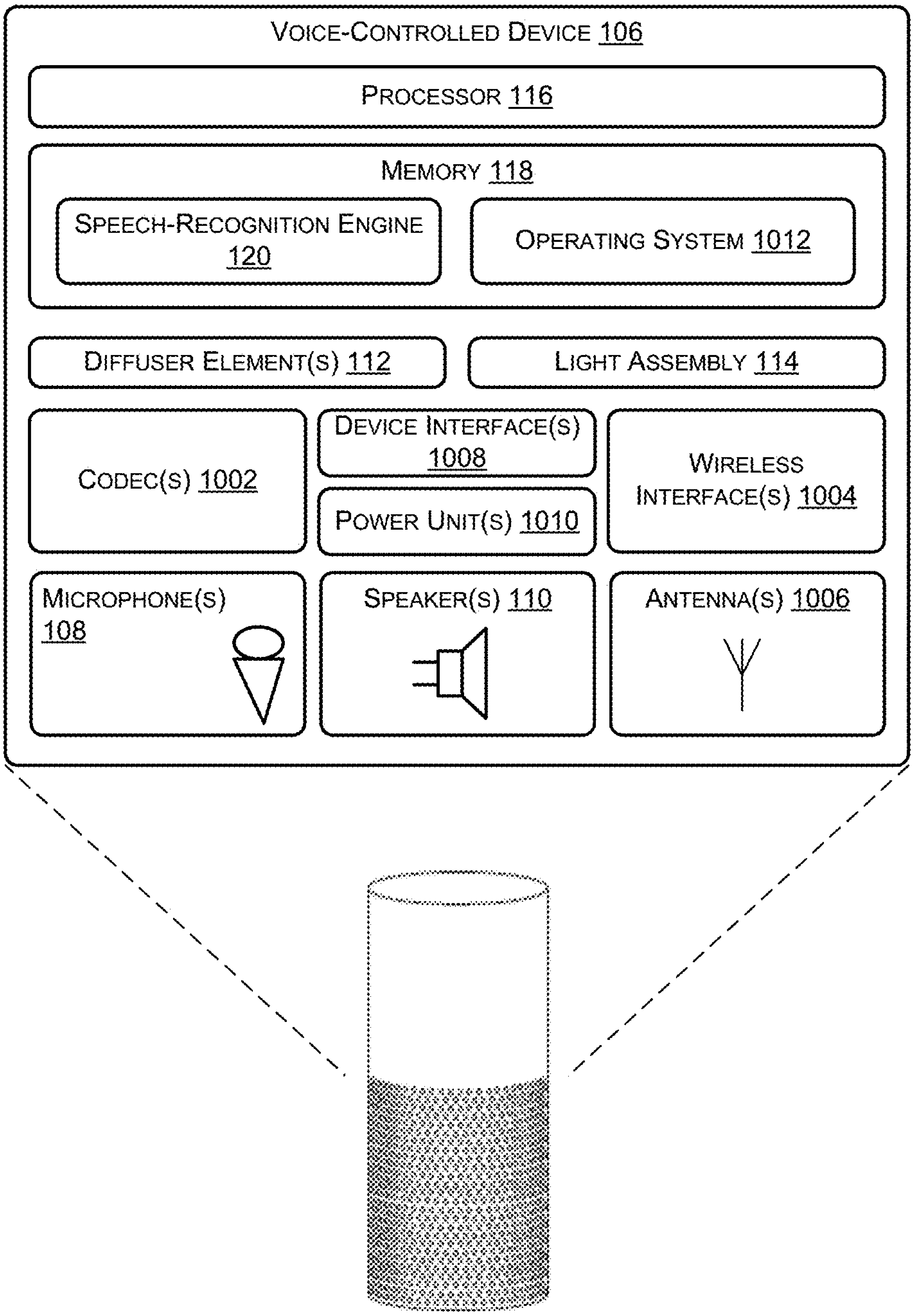
VOICE-CONTROLLED DEVICE 106
PROCESSOR 116
MEMORY 118
SPEECH-RECOGNITION ENGINE 120
OPERATING SYSTEM 1012
DIFFUSER ELEMENT(S) 112
LIGHT ASSEMBLY 114
CODEC(S) 1002
DEVICE INTERFACE(S) 1008
POWER UNIT(S) 1010
WIRELESS INTERFACE(S) 1004
MICROPHONE(S) 108
SPEAKER(S) 110
ANTENNA(S) 1006

Fig. 10

LIGHT ASSEMBLIES FOR ELECTRONIC DEVICES

RELATED APPLICATIONS

This application is a continuation of and claims priority to U.S. patent application Ser. No. 16/192,106, filed Nov. 15, 2018, which is a continuation of U.S. patent application Ser. No. 15/417,895, filed Jan. 27, 2017, now U.S. Pat. No. 10,162,106, issued Dec. 25, 2018, which is a continuation of U.S. patent application Ser. No. 14/502,429, filed Sep. 30, 2014, now U.S. Pat. No. 9,574,762, issued Feb. 21, 2017, the entire disclosures of which are incorporated herein by reference.

BACKGROUND

Homes are becoming more wired and connected with the proliferation of computing devices such as desktops, tablets, entertainment systems, and portable communication devices. As computing devices evolve, many different ways have been introduced to allow users to interact with these devices, such as through mechanical means (e.g., keyboards, mice, etc.), touch screens, motion, and gesture. Another way to interact with computing devices is through speech.

BRIEF DESCRIPTION OF THE DRAWINGS

The detailed description is described with reference to the accompanying figures. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. The use of the same reference numbers in different figures indicates similar or identical components or features.

FIG. **1** shows an illustrative voice interaction computing architecture set in a home environment. The architecture includes a voice-controlled device physically situated in the home and communicatively coupled to remote computing resources. The voice-controlled device includes a microphone to receive voice commands, a light ring to provide visual cues to a user issuing the commands, and speakers for outputting audio to the user.

FIG. **2** illustrates an example embodiment of a layout of components of the voice-controlled device of FIG. **1**.

FIG. **3** illustrates two speakers and two diffuser elements that certain embodiments of the voice-controlled device may include.

FIG. **4** illustrates an example scenario where sound emanating from the speakers shown in FIG. **3** travels substantially downwards before contacting the diffuser elements of FIG. **3** and traveling outwards, substantially uniformly in all horizontal directions.

FIG. **5** illustrates an example process for assembling an electronic device that includes one or more speakers pointed away from an end of a housing at which a microphone resides. By positioning the speakers to point away from the microphone, audio signals generated by the microphone include less noise from the speakers, thereby reducing the amount of acoustic echo cancelation needed to isolate voice commands received at the device.

FIG. **6** illustrates an example embodiment of a light assembly, which the voice-controlled device of FIG. **1** may include for providing visual indications to a user of the device. In this example, multiple lighting elements (e.g., LEDs) couple to a bottom surface of a substrate. When one of the lighting elements is powered, the powered lighting element emits light substantially downwards and towards a light reflector, which includes multiple cavities (e.g., one cavity for each lighting element). The surface of the light reflector may reflect the light from the lighting element upwards towards the light ring, which may illuminate in response.

FIG. **7** illustrates an example embodiment of a light reflector including multiple cavities that receive respective lighting elements and that reflect upwards light received from the lighting elements.

FIG. **8** illustrates an example embodiment of a light ring coupled to vertical walls of a reflector housing, which may hold the light reflector of FIG. **7**.

FIG. **9** illustrates an example process for assembling an electronic device that includes a light assembly for providing visual feedback to a user of the device.

FIG. **10** shows a block diagram of selected functional components implemented in the voice-controlled device of FIG. **1**.

DETAILED DESCRIPTION

This disclosure describes, in part, electronic devices that include light assemblies for providing visual feedback to users that operate the electronic devices. In some instances, the devices comprise voice-controlled devices and, therefore, include one or more microphones for receiving audible commands from the users. After receiving a command, for instance, one such voice-controlled device may cause a corresponding light assembly of the device to illuminate in some predefined manner. This illumination may indicate to the user that device has received the command. In other instances, the devices may illuminate the lighting assembly for an array of other purposes. For instance, one such device may illuminate the corresponding light assembly when powering on or off, playing music, outputting information to a user (e.g., via a speaker or display), or the like.

In some instance, the voice-controlled device may comprise a housing that houses some or each component of the device. This housing may, in some instances, have a substantially uniform cross-sectional shape, such as a circle, square, triangle, or any other polygon. In some instances, the housing is cylindrical and includes one or more microphones near a first end of the cylindrical housing (e.g., a top of the housing when the device is standing up), as well as a light guide (e.g., a light ring) at or near a top of the housing. The light ring may comprise a single light pipe such that light received at a discrete portion of the light pipe diffuses to other locations near the discrete point. Further, while in some instances this element comprises a "ring", in other instances this light guide may take any other shape.

In addition, the device may include, near the top of the housing, a substrate having a bottom surface that includes multiple lighting elements, such as LEDs or the like. The device may include a controller that is able to power individual ones of the multiple lighting elements. For instance, the substrate may include any number of lighting elements (e.g., one, two, three, sixteen, one hundred, etc.), distributed substantially equally about a perimeter of the bottom surface of the substrate, while the controller may control one or more of the lighting elements individually at any time.

The device may further include a light reflector, underneath the substrate that includes the lighting elements. When the controller powers one or more of the lighting elements, the lighting elements may emit light downwards towards the light reflector and away from the light ring. The light reflector, which may also take the cross-sectional shape of the housing (e.g., circular in the case of the cylindrical housing) may include one or more cavities for receiving the emitted light of the lighting elements. In some instances, the light reflector includes one cavity for each lighting element coupled to the bottom surface of the substrate. Further, the lighting elements may sit within the cavities of the light reflector. When light from the lighting elements emits substantially downwards, the light may strike surfaces of the respective cavities, which may reflect the light substantially upwards and towards the light ring on the top of the cylindrical housing. Upon receiving the reflected light, the light ring illuminates at and near where the light hits the light ring. Because the light ring may reside on vertical walls of the cylindrical housing, the light ring may reside above each other component of the electronic device and may represent the highest point of the device. Therefore, the illuminated light ring may be visible to the user from each side of the device at any or most locations within a room.

In some instances, the light ring attaches to a component that rotates about a longitudinal axis of the cylindrical housing. For instance, the light ring may sit atop vertical walls of a light-reflector housing that includes a bottom surface and vertical walls. The light reflector as well as the substrate housing the lighting elements on the bottom surface of the substrate may reside at least partly within the light-reflector housing. However, the light-reflector housing—and the light ring attached thereto—may attach to a remainder of the cylindrical housing such that the light-reflector housing rotates freely about the longitudinal axis. The light reflector and the substrate housing the lighting elements, however, may remain stationary. In some instances, the rotation of the light-reflector housing may control functionality of the device. For instance, rotation of the light-reflector housing may control a volume or sound of the device (clockwise for additional volume, counterclockwise for less volume), a brightness of a display, a brightness of the lights, whether the device is powered on or off, or the like.

Given that the light ring comprises a single element, such as a single light pipe, the light ring may illuminate at the proper location regardless of the freedom of the light-reflector housing to rotate about the longitudinal axis. For instance, envision that a first of sixteen lighting elements resides at a far left side of the cylindrical housing and is illuminated by a controller. Light from this lighting element may emit downwards into a respective cavity of the light reflector, which may in turn reflect the light upwards towards the light ring. The light ring may receive and partially diffuse the received light at and near where it is received, regardless of which section of the continuous, uniform light pipe receives the light.

In some instances, the voice-controlled device may further include one or more speakers for outputting audio. In some instances, the device includes at least one speaker within the cylindrical or other-shaped housing, with the speaker aimed or pointed away from the microphone. For instance, if the microphone resides at or near the top of the cylindrical housing, then the speaker may point downwards along the longitudinal axis of the housing and away from the microphone. By pointing the speaker away from the microphone, the microphone will receive less sound from the speaker than if the speaker were pointed otherwise (e.g., toward the microphone). Because the voice-controlled device may perform speech recognition on audio signals generated by the microphone, less sound from the speaker represented in the audio signal (e.g., from music playing by the speakers) may result in more accurate speech recognition, and/or a lesser need to perform acoustic echo cancelation (AEC) on the generated audio signals.

In some instances, the device may also include a diffuser element that diffuses sounds in a direction other than along the longitudinal axis. For instance, the diffuser element may comprise an element substantially uniform shape (e.g., a rounded top of a sphere, a cone, etc.) that diffuses sound traveling from the speaker, down the longitudinal axis, and out into a plane horizontal to the longitudinal axis. Further, the cylindrical housing may comprise a mesh of holes or other voids in order to allow the sound waves to easily escape the inside of the cylindrical housing. Further, because the diffuser element is substantially uniform, the sound may be diffused or dispersed substantially equally all the way around the device.

In some instances, the voice-controlled device includes multiple speakers, in-line with one another and pointed in a same direction. For instance, the device may include two speakers, both pointed downwards away from the microphone of the device. Further, the device may include, directly beneath each speaker, a respective diffuser element for diffusing sound from each respective speaker. Therefore, the sound from each speaker diffuses outwards substantially equally around the entire perimeter of the device.

The devices and techniques introduced above may be implemented in a variety of different architectures and contexts. One non-limiting and illustrative implementation is described below.

FIG. **1** shows an illustrative voice interaction computing architecture **100** set in a home environment **102** that includes a user **104**. The architecture **100** also includes an electronic voice-controlled device **106** with which the user **104** may interact. In the illustrated implementation, the voice-controlled device **106** is positioned on a table within a room of the home environment **102**. In other implementations, it may be placed or mounted in any number of locations (e.g., ceiling, wall, in a lamp, beneath a table, under a chair, etc.). Further, more than one device **106** may be positioned in a single room, or one device may be used to accommodate user interactions from more than one room.

Generally, the voice-controlled device **106** has a microphone unit comprising at least one microphone **108** and a speaker unit comprising at least one speaker **110** to facilitate audio interactions with the user **104** and/or other users. As introduced above, the device **106** may also include one or more diffuser elements for diffusing sound from the speaker about the device **106**. In some instances, the voice-controlled device **106** is implemented without a haptic input component (e.g., keyboard, keypad, touch screen, joystick, control buttons, etc.) or a display. In certain implementations, a limited set of one or more haptic input components may be employed (e.g., a dedicated button to initiate a configuration, power on/off, etc.). Nonetheless, the primary and potentially only mode of user interaction with the electronic device **106** may be through voice input and audible output.

The voice-controlled device may further include a light assembly **116** as introduced above. The light assembly **116** may comprise a light ring atop the device **106** for providing visual feedback to the user **104**. One example implementation of the voice-controlled device **106** is provided below in more detail with reference to FIG. **10**.

The microphone **108** of the voice-controlled device **106** detects audio from the environment **102**, such as sounds uttered from the user **104**. As illustrated, the voice-controlled device **106** includes a processor **116** and memory **118**, which stores or otherwise has access to a speech-recognition engine **120**. As used herein, a processor may include multiple processors and/or a processor having multiple cores. The speech-recognition engine **120** performs speech recognition on audio signals generated based on sound captured by the microphone, such as utterances spoken by the user **104**. The voice-controlled device **106** may perform certain actions in response to recognizing different speech from the user **104**. The user may speak predefined commands (e.g., “Awake”; “Sleep”), or may use a more casual conversation style when interacting with the device **106** (e.g., “I’d like to go to a movie. Please tell me what’s playing at the local cinema.”).

In some instances, the voice-controlled device **106** may operate in conjunction with or may otherwise utilize computing resources **122** that are remote from the environment **102**. For instance, the voice-controlled device **106** may couple to the remote computing resources **122** over a network **124**. As illustrated, the remote computing resources **122** may be implemented as one or more servers and may, in some instances, form a portion of a network-accessible computing platform implemented as a computing infrastructure of processors, storage, software, data access, and so forth that is maintained and accessible via a network such as the Internet. The remote computing resources do not require end-user knowledge of the physical location and configuration of the system that delivers the services. Common expressions associated for these remote computing resources include “on-demand computing”, “software as a service (SaaS)”, “platform computing”, “network-accessible platform”, “cloud services”, “data centers”, and so forth.

The servers may include a processor **126** and memory **128**. As illustrated, the memory **128** may store and utilize a speech-processing engine **130** for receiving audio signals from the device **106**, recognizing speech and, potentially, causing performance of an action in response. For instance, the engine **130** may identify speech within an audio signal by performing natural language understanding (NLU) techniques on the audio signal. In addition, the engine **130** may provide audio for output on a client device (e.g., the device **106**) via text-to-speech (TTS). In some examples, the voice-controlled device **106** may upload audio data to the remote computing resources **122** for processing, given that the resources **122** may have a computational capacity that far exceeds the computational capacity of the voice-controlled device **106**. Therefore, the voice-controlled device **106** may utilize the speech-processing engine **130** for performing relatively complex analysis on audio captured from the environment **102**.

Regardless of whether the speech recognition occurs locally or remotely from the environment **102**, the voice-controlled device **106** may receive vocal input from the user **104** and the device **106** and/or the resources **122** may perform speech recognition to interpret a user’s operational request or command. The requests may be for essentially any type of operation, such as database inquires, requesting and consuming entertainment (e.g., gaming, finding and playing music, movies or other content, etc.), personal management (e.g., calendaring, note taking, etc.), online shopping, financial transactions, and so forth. In some instances, the device **106** also interacts with a client application stored on one or more client devices of the user **104**.

The voice-controlled device **106** may communicatively couple to the network **124** via wired technologies (e.g., wires, USB, fiber optic cable, etc.), wireless technologies (e.g., WiFi, RF, cellular, satellite, Bluetooth, etc.), or other connection technologies. The network **124** is representative of any type of communication network, including data and/or voice network, and may be implemented using wired infrastructure (e.g., cable, CATS, fiber optic cable, etc.), a wireless infrastructure (e.g., WiFi, RF, cellular, microwave, satellite, Bluetooth, etc.), and/or other connection technologies.

FIG. **2** illustrates an example embodiment of components of the voice-controlled device of FIG. **1**. First, the device **106** may comprise a housing **202** to which some or all of the remaining components of the device **106**. In this example, the housing **202** comprises a cylindrical housing having a circular cross-section, although the housing **202** may take any other shape. Here, the housing **106** includes a solid portion near a top of the housing **202** and a mesh of holes around a perimeter nearer a bottom of the housing **202**. These holes may allow for better airflow and, therefore, output of audio from the speaker(s) of the device **106**. In some instances, the housing **202** comprises a plastic that has been extruded with laser-cut holes. In other instances, the housing **202** comprises metal or any other material and includes slots or other features for allowing sound to exit from inside the housing **202**. In this illustrated example, the device **106** further includes a scrim **204** for protecting components within the housing **202**.

As the reader will appreciate, some or all of the elements shown to the left of the housing may reside at least partly within the housing **202** when assembled. As illustrated, the top of housing **202** may include the light assembly **114**, above which may reside portions of the sub-system of the device for capturing sound and generating audio signals (e.g., for identifying audible commands of a user). First, the device is shown to include a microphone grill **206**, a top plate **208**, one or more buttons **210**, a microphone mesh **212**, and an audio PCBA **214**, which may house one or more microphones on its top surface. The top plate **208** includes holes to receive the buttons **210**, which may be used to operate the device (e.g., power on and off, mute or unmute the microphones, etc.). The microphone mesh **212**, meanwhile, may comprise a layer having a mesh of holes to allow sound to reach the microphone(s) on the top surface of the audio PCBA **214**. Again, in some instances, each hole in these components may be laser cut for accuracy and precision.

An underside or bottom surface of the audio PCBA **214** may house one or more lighting elements, such as LEDs or the like. In some instances, these lighting elements may reside near a perimeter of the PCBA **214** and may be distributed substantially equally (i.e., may have equal spacing between one another). Beneath the audio PCBA **214** resides a gear encoder **216** and a light reflector **218**. As introduced above, the light reflector **218** may reflect light emitted downwards back upwards toward a light ring discussed below. The light reflector **218** may be shaped as a ring and may include an equal number of cavities as lighting elements disposed on the bottom surface of the PCBA **214**.

Underneath the light reflector **218**, the device **106** may include a clamp plate **220**, a light ring **222**, and a light-reflector housing **224**. The clamp plate **220** may secure the light reflector **218** in place when it is disposed inside the vertical walls of the light-reflector housing **224**. The light reflector housing **224** may, as described above, attach to a top of the housing **202** in such as way as to rotate freely about the longitudinal axis of the housing **202** (e.g., to change a volume or other attribute of the device). As such, the light-reflector housing **224** may essentially comprise a rotating knob. The light ring **222**, meanwhile, may reside atop vertical walls of the light-reflector housing **224**. As such, the light ring **222** may be viewable from each side of the device and may also rotate freely about the longitudinal axis. Further, because the light ring **222** may comprise a single element (e.g., a single light pipe), light that is reflected off of the light reflector **218** may illuminate the light ring **222** at the proper location regardless of the state of rotation of the light-reflector housing **224**. Finally, the device **106** may include an attaching plate **226** that secures the light-reflector housing **224** (and the components residing therein) onto the housing **202** in a rotatable manner.

Moving downwards within the device **106**, the device **106** may further include an audio assembly for outputting audio within an environment in which the device **106** resides. This sub-system of the device **106** may first include a speaker housing **228** for housing one or more speakers, in addition to a main PCBA **230**, and flexible cable **232**. The main PCBA **230** may, in this example, house certain hardware components of the device (e.g., processors, physical memory, etc.), while the cable **232** may route power and electrical signals amongst the components of the device **106**.

Next, the device includes a port **234**, a first speaker **236**, a first diffuser element **238**, a second speaker **240**, and a second diffuser element **242**. The first and second speakers may be in line with one another and pointed downwards along the longitudinal axis of the housing **202** and away from the microphone disposed on the top surface of the audio PCBA **214**. In some instances these speakers are the same size, while in other instances they differ and, therefore, output sound of different frequency ranges.

The first diffuser element **242**, meanwhile, may reside between the first speaker **236** and the second speaker **240** and may function to diffuse sound coming from the first speaker **236** outwards towards a horizontal plane relative to the device **106**. In some instances, as illustrated in FIG. **3**, the first diffuser element **242** includes a rounded surface for causing the sound waves from the first speaker **136** to move outwards, through the mesh of holes in the housing **202**. The second diffuser element **242** may function similarly, albeit for the second speaker **240**. The second diffuser element **242** may also include some sort of shape for causing the sound waves to travel outside of the housing towards the horizontal plane, such as a rounded top surface (e.g., partially spherical), a cone-shaped element, or the like. In some instances, the second diffuser element **242** may also comprise a housing base on which the housing **202** stands.

Finally, in this example, the device **106** includes a connector PCBA **244**, a bottom plate **246**, and a foot element **248**. Further, a power source may reside within a cavity of the foot element **248** such that the bulk of the power source is within the housing **202** and the only portion of the power source outside of the housing **202** is a power cord running to an outlet. The foot element may reside within a cavity of the diffuser element **242** in some instances, and may comprise a rubber or other type of material having a high static coefficient of friction to provide stability to the device **106** when standing. The bottom plate **246** may couple the foot element **248** to the diffuser element **242**, while the connector PCBA **244** may house electrical components for passing power up to other components of the device.

FIG. **3** illustrates, in further detail, the two speakers and two diffuser elements introduced in FIG. **2** above. As illustrated, both speakers point downwards in this example, although in other implementations the speakers can point in any direction (e.g., upwards, sideways, at an acute angle, etc.). Generally, the speakers point away from a location of the microphone of the device **106** so as to increase the signal-to-noise ratio (SNR) of any audio signals generated by the microphone.

In addition, FIG. **3** illustrates an implementation of the first diffuser element **238** at a greater level of detail. In this example, the first diffuser element **238** includes a top surface **302** that is rounded in a uniform manner all the way around the first diffuser element **238** (e.g., uniform in 360 degrees about the longitudinal axis). Further, this rounded top surface **302** may, in some instances, resemble a top portion of a flattened sphere. This top surface **302** functions to receive air carrying sound waves from the first speaker **236** and direct these sounds waves outwards horizontally in a substantially uniform manner about the longitudinal axis of the device **106**.

The second diffuser element **242** is also shown in greater detail. AS illustrated, in this example the second diffuser element **242** includes a top surface **304** comprising a cone. This cone similarly functions to receive air carrying sound waves from the second speaker **240** and direct these sounds waves outwards horizontally in a substantially uniform manner about the longitudinal axis of the device **106**. While FIG. **3** illustrates a flattened sphere and a cone sitting atop the diffuser elements, the reader will appreciate that other implementations may utilize other shapes for diffusing the sound horizontally.

FIG. **4** illustrates an example scenario where sound **402** emanating from the speakers shown in FIG. **3** travels substantially downwards before contacting the diffuser elements of FIG. **3** and traveling outwards, substantially uniformly in all horizontal directions. For instance, FIG. **4** illustrates that sound **402** emanating from the first speaker **236** contacts the first diffuser element **238**, which directs this sound outwards substantially in a plane that is horizontal to the longitudinal axis of the device **106** in a substantially uniform manner. Further, sound **404** emanating from the second speaker **240** contacts the second diffuser element **242**, which also directs this sound outwards in a substantially uniform manner.

FIG. **5** illustrates an example process **500** for assembling an electronic device that includes one or more speakers pointed away from an end of a housing at which a microphone resides. By positioning the speakers away from the microphone, input signals generated by the microphone include less noise from the speakers, thereby reducing the amount of acoustic echo cancelation needed to isolate commands received at the microphone.

The process **500** includes, at **502**, coupling a first speaker to and at least partly within a housing such that the first speaker points along a longitudinal axis of the housing and towards a first end of the housing. Next, at **504**, the process **500** couples a second speaker to and at least partly within the housing such that the second speaker also points along the longitudinal axis of the housing and towards the first end of the housing.

At **506**, the process **500** couples a first diffuser element to the housing at least partly between the first and second speakers, the first diffuser element configured to diffuse sound about a horizontal plane perpendicular to the longitudinal axis of the housing. At **508**, the process **500** couples a second diffuser element to the housing, nearer the first end of the housing than both the first and second speakers, the second diffuser element configured to diffuse sound about the horizontal plane perpendicular to the longitudinal axis of the housing. Finally, at **510**, the process **500** may couple a microphone to the housing near a second, opposite end of the housing.

FIG. **6** illustrates an example embodiment of the light assembly **114**, which the voice-controlled device **106** may include for providing visual indications to a user of the device. In this example, multiple lighting elements **602(1)**, . . . , **602**(N) couple to a bottom surface of a substrate, which in this example comprises the audio PCBA **214** (although the lighting elements may couple to any other substrate). Further, these lighting elements may, in some instances be disposed equally along an edge of a perimeter of the substrate. In some instances, a bottom surface of the audio PCBA **214** (or other substrated) is coated in a light-reflective material for the purpose of increasing light reflection.

When one of the lighting elements is powered by a controller of the device, the powered lighting element emits light substantially downwards and towards the light reflector **218**, which includes multiple cavities (e.g., one cavity for each lighting element). The surface of the light reflector **218**, potentially along with an inner surface of the vertical walls of the light-reflector housing **224**, may reflect the light from the lighting element upwards towards the light ring **222**, which may illuminate in response. In some instances, and as illustrated, the cavities of the light reflector **218** may include light-spreading elements for reflecting the light in certain directions. In this example, these elements have a triangular cross-section, although in other embodiments the elements may have a different shape (e.g., conical, sloping, etc.).

FIG. **7** illustrates an example embodiment of the light reflector **218** that is circular in shape and that may receive the light from the lighting elements **602(1)**-(N) and reflect it generally upwards towards the light ring **222**. In this example, the light reflector **218** includes multiple cavities **702(1)**, . . . , **702(12)** that receive respective lighting elements **602(1)**-(N) when the audio PCBA **214** (or other substrate holding the lighting elements) is coupled to the light reflector. Surfaces of these cavities **702(1)-(12)** may receive the emitted light and reflect this light upwards. It is noted that while the light reflector **218** includes twelve cavities in this example (and, hence, the audio PCBA **214** may include twelve complementary lighting elements to reside at least partially within these cavities), the light reflector **218** may include any other number of cavities, which may be spaced substantially equally about the perimeter of the light reflector **218**.

In addition, FIG. **7** illustrates that the light reflector **218** may include, adjacent to each cavity, a corresponding light-spreading element **704(1)**. While FIG. **7** illustrates a single light-spreading element **704(1)** adjacent to the cavity **702(1)**, FIG. **7** illustrates that each cavity may be associated with a corresponding light-spreading element. The light-spreading element **704(1)** may function to spread light that is received in the cavity prior to the light be reflected back upwards towards the light ring. That is, when the lighting elements emit light into the cavities, the cavities may reflect the light first toward the light-spreading elements, which may spread the light in different directions and back into the cavities, which in turn reflects the light upwards towards the light ring. By doing so, the light is further dispersed prior to reaching the light ring, which in turn diffuses the light even further for a more even illumination. While in this example the light-spreading element **704(1)** comprises a triangular shape, in other implementations this element **704(1)** may take any other shape.

FIG. **8** illustrates an example embodiment of the light ring **222** coupled to vertical walls of the light-reflector housing **224**. The light ring **222** may comprise the singular light pipe and may be made of a diffusive material for diffusing light to locations near where the light pipe receives the light. Further, the light ring **22** may reside at the vertical walls of the light-reflector housing and, therefore, may comprise the highest point of the device **106**.

FIG. **9** illustrates an example process **900** for assembling an electronic device that includes a light assembly for providing visual feedback to a user of the device. At **902**, the process **900** places a light reflector, having multiple cavities on a top side of the light reflector, inside a reflector housing having a horizontal surface and vertical walls, wherein the reflector housing includes a light ring atop the vertical walls. At **904**, the process **900** places a substrate onto the light reflector, the substrate including multiple lighting elements on a bottom surface of the substrate, each of multiple lighting elements residing at least partially within one of the multiple cavities of the light reflector when the substrate is placed onto the light reflector. Finally, at **906**, the process **900** powers one of the multiple lighting elements, the powered lighting element emitting light substantially downwards into its respective cavity, a surface of the respective cavity reflecting the light substantially upwards towards the light ring, a portion of the light ring receiving the reflected light and illuminating.

FIG. **10** shows selected functional components of one implementation of the voice-controlled device **106** in more detail. Generally, the voice-controlled device **106** may be implemented as a standalone device that is relatively simple in terms of functional capabilities with limited input/output components, memory and processing capabilities. For instance, the voice-controlled device **106** does not have a keyboard, keypad, or other form of mechanical input in some implementations, nor does it have a display or touch screen to facilitate visual presentation and user touch input. Instead, the device **106** may be implemented with the ability to receive and output audio, a network interface (wireless or wire-based), power, and limited processing/memory capabilities.

In the illustrated implementation, the voice-controlled device **106** includes the processor **116** and memory **118**. The memory **118** may include computer-readable storage media ("CRSM"), which may be any available physical media accessible by the processor **116** to execute instructions stored on the memory. In one basic implementation, CRSM may include random access memory ("RAM") and Flash memory. In other implementations, CRSM may include, but is not limited to, read-only memory ("ROM"), electrically erasable programmable read-only memory ("EEPROM"), or any other medium which can be used to store the desired information and which can be accessed by the processor **116**.

The voice-controlled device **106** includes a microphone unit that comprises one or more microphones **108** to receive audio input, such as user voice input. The device **106** also includes a speaker unit that includes one or more speakers **110** to output audio sounds. The device **106** also includes the diffuser elements **112** and the light assembly **114**, described above.

One or more codecs **1002** are coupled to the microphone(s) **108** and the speaker(s) **110** to encode and/or decode the audio signals. The codec may convert audio data between analog and digital formats. A user may interact with the device **106** by speaking to it, and the microphone(s) **108** captures sound and generates an audio signal that includes the user speech. The codec(s) **1002** encodes the user speech and transfers that audio data to other components. The device **106** can communicate back to the user by emitting audible statements through the speaker(s) **110**. In this manner, the user interacts with the voice-controlled device simply through speech, without use of a keyboard or display common to other types of devices.

In the illustrated example, the voice-controlled device **106** includes one or more wireless interfaces **1004** coupled to one or more antennas **1006** to facilitate a wireless connection to a network. The wireless interface(s) **1004** may implement one or more of various wireless technologies, such as wifi, Bluetooth, RF, and so on.

One or more device interfaces **1008** (e.g., USB, broadband connection, etc.) may further be provided as part of the device **106** to facilitate a wired connection to a network, or a plug-in network device that communicates with other wireless networks. One or more power units **1010** are further provided to distribute power to the various components on the device **106**.

The voice-controlled device **106** is designed to support audio interactions with the user, in the form of receiving voice commands (e.g., words, phrase, sentences, etc.) from the user and outputting audible feedback to the user. Accordingly, in the illustrated implementation, there are no or few haptic input devices, such as navigation buttons, keypads, joysticks, keyboards, touch screens, and the like. Further there is no display for text or graphical output. In one implementation, the voice-controlled device **106** may include non-input control mechanisms, such as basic volume control button(s) for increasing/decreasing volume, as well as power and reset buttons. There may also be one or more simple lighting elements (e.g., LEDs around perimeter of a top portion of the device) to indicate a state such as, for example, when power is on or to indicate when a command is received. But, otherwise, the device **106** does not use or need to use any input devices or displays in some instances.

Several modules such as instruction, datastores, and so forth may be stored within the memory **118** and configured to execute on the processor **116**. An operating system module **1012** is configured to manage hardware and services (e.g., wireless unit, Codec, etc.) within and coupled to the device **106** for the benefit of other modules. In addition, the memory **118** may include the speech-recognition engine **120**, discussed above.

Although the subject matter has been described in language specific to structural features, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features described. Rather, the specific features are disclosed as illustrative forms of implementing the claims.

What is claimed is:

1. A method comprising:

receiving, at one or more processors, an audio signal generated by one or more microphones, the one or more processors being disposed on a first surface of a substrate; and

causing, by the one or more processors and based at least in part on the audio signal, a light element driver to illuminate a light element, the light element driver being disposed on the first surface of the substrate and the light element being disposed on a second surface of the substrate that is opposite the first surface.

2. The method of claim **1**, further comprising causing, by the one or more processors, a speaker to output sound, wherein the one or more microphones are oriented in a first direction and the speaker is oriented in a second direction that is different than the first direction.

3. The method of claim **2**, wherein the speaker is located closer to a bottom of an electronic device than the substrate.

4. The method of claim **1**, wherein:

the one or more processors comprise one or more first processors and one or more second processors;

the one or more first processors receive the audio signal; and

the one or more second processors cause the light element driver to illuminate the light element.

5. The method of claim **1**, wherein the one or more microphones, the substrate, the light element driver, and the light element are components of a first device, the method further comprising:

sending, by the one or more processors to a second device, first audio data associated with the audio signal; and

receiving, at the one or more processors from the second device, second audio data.

6. The method of claim **1**, wherein the one or more microphones are disposed on the first surface of the substrate.

7. The method of claim **1**, further comprising determining, by the one or more processors, a presence of a predefined wakeword within the audio signal, and wherein causing the light element driver to illuminate the light element is based at least in part on determining the presence of the predefined wakeword.

8. A method comprising:

receiving, by one or more processors and from one or more microphones, an audio signal representing user speech, wherein the one or more processors and the one or more microphones are disposed on a first side of a printed circuit board (PCB); and

causing, by the one or more processors and based at least in part on the audio signal or the user speech, a light element to illuminate, wherein the light element is disposed on a second side of the PCB that is opposite the first side.

9. The method of claim **8**, wherein causing the light element to illuminate comprises causing, by the one or more processors, a light element driver to illuminate the light element, wherein the light element driver is disposed on the first side of the PCB.

10. The method of claim **8**, wherein:

the one or more processors comprise one or more first processors and one or more second processors;

the one or more first processors receive the audio signal; and

the one or more second processors cause the light element to illuminate.

11. The method of claim **8**, further comprising causing, by the one or more processors, a speaker to output sound that represents a response to the user speech.

12. The method of claim **11**, wherein:

the PCB and the speaker reside within a housing of a device; and

the one or more microphones are disposed closer to a top of the device than the speaker.

13. The method of claim **8**, further comprising determining, by the one or more processors, a presence of a predefined wakeword within the audio signal, and wherein causing the light element to illuminate is based at least in part on determining the presence of the predefined wakeword.

14. The method of claim **8**, wherein the light element is optically coupled to a light diffuser.

15. One or more non-transitory computer-readable media storing instructions that, when executed by one or more processors, cause the one or more processors to perform operations comprising:

receiving an audio signal generated by one or more microphones; and

causing, based at least in part on receiving the audio signal, a light element driver to illuminate a light element, wherein the one or more processors and the light element driver are disposed on a first surface of a substrate, and the light element is disposed on a second surface of the substrate that is opposite the first surface.

16. The one or more non-transitory computer-readable media of claim **15**, wherein the one or more microphones are disposed on the first surface of the substrate.

17. The one or more non-transitory computer-readable media of claim **15**, the operations further comprising causing a speaker to output sound associated with the audio signal.

18. The one or more non-transitory computer-readable media of claim **15**, wherein the light element is configured to illuminate according to an operational state of the one or more processors.

19. The one or more non-transitory computer-readable media of claim **15**, wherein the audio signal is received at a first device, the operations further comprising:

sending, to a second device, first audio data associated with the audio signal; and

receiving, from the second device, second audio data for output at the first device or a third device communicatively coupled to the first device.

20. The one or more non-transitory computer-readable media of claim **15**, the operations further comprising receiving, from a haptic input device, data associated with a touch input.

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